TMOD Technology and Science Program News

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In This Issue

Charles Stelzried and Michael Klein

In this issue's lead article, Leslie Deutsch, the manager of the Telecommunications and Mission Operations Directorate (TMOD) Technology (TMOT) Program, describes the logic behind the recent TMOD reorganization. TMOD will become more responsible for spacecraft functions. It will provide a single organization that is responsible for the end-to-end system and will result in a higher infusion of new technology into the deep space communications and operations system. The number of simultaneous, deep space missions is expected to grow from about 10 today to over 25 by 2003. It is especially important that new technology provide increased efficiencies with resultant lower costs, since TMOD must provide all of the current services to these additional missions with a budget that is not expected to grow.

Roger Linfield describes an advanced calibration system for determining tropospheric parameters being developed for the Cassini Radio Science experiments. The success of this effort will determine the ultimate sensitivity of the Gravitational Wave Experiment. A factor of two improvement, relative to current water vapor radiometers (WVR) emission coefficient of water vapor, is required for this new system. It is expected that this can be accomplished using comparisons between Global Positioning System (GPS) and WVR calibrations of microwave delay from the earth's troposphere. Comparisons at a warm, humid site, such as Florida or Hawaii, will be made for this purpose.

Paul Richter and David Rochblatt provide details for a proposed raster scan technique of radio sources for calibration of Deep Space Network (DSN) antennas. This is expected to improve the accuracy relative to the current radio source boresight method. The boresight method is particularly susceptible to errors using radio sources that are not point sources and are not 'uniform' in brightness. Improved station instrumentation for taking data 'on the fly' is needed and currently under development at the TMOD Goldstone DSS13 research 34 m Beam Waveguide (BWG) antenna. It is expected that this will reduce the uncertainty of a typical X-band (8.4 GHz) radio source noise temperature measurement from about 0.14 K to about 0.03 K.

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TMOD Reorganization: Changes for the Better

Leslie J. Deutsch

Introduction

These days, at the Jet Propulsion Laboratory (JPL), reorganization seems to be the norm rather than the exception. With all of the organizational changes occurring around us, it is sometimes difficult to see the logic behind it all. This article explains the logic behind the recent reorganization of the Telecommunications and Mission Operations Directorate (TMOD), and how it has already impacted our technology program.

A New Role for TMOD

Before there was a TMOD reorganization, there was a redefinition of the role TMOD will play in JPL's future. Part of this is enabled by the new service paradigm (I was hoping I could avoid that word!). TMOD is in the business of supplying services to its customers — mostly flight projects or ground-based scientists. In this new language, the changing role of TMOD at JPL can be explained by the breadth of the services it provides.

As an example, TMOD has always been in the business of providing telemetry services for its customers. The old definition of this service might be expressed: "If you throw bits down toward me out of the sky, I will catch them and send those I caught to your facility on Earth." The new definition of a telemetry service might be stated as: "If you place information in a certain

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part of your spacecraft, I will move it to your facility on Earth."

Although both definitions are valid, the second implies a much greater role for TMOD. In particular, TMOD will become more and more responsible for functions that take place on the spacecraft. Figure 1 is an information theoretic model. In the Figure, TMOD is responsible for a three-layer stack of services that connect the spacecraft instruments and engineering systems with their counterparts on the ground.

By making TMOD responsible for the entire stack for JPL missions, we can promote commonality in engineering solutions. This is bound to result in cost savings for the National Aeronautics and Space Administration (NASA). In addition, and of great importance to the technology program, by having a single organization in charge of the evolution of the end-to-end system, we have a better chance of infusing new technology, as time progresses.

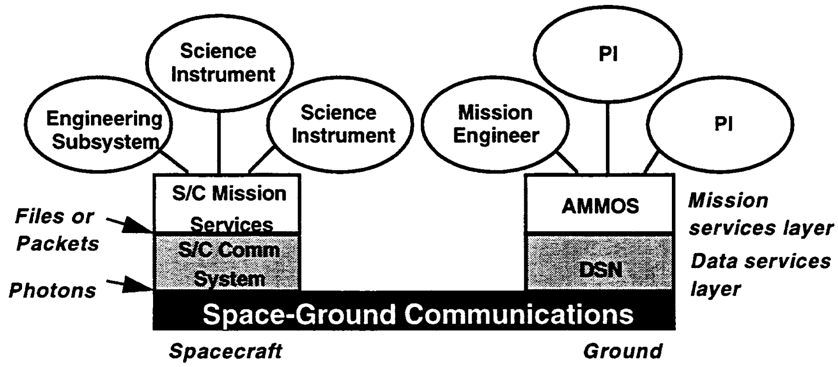

FIGURE 1. INFORMATION THEORETIC MODEL OF TMOD

The Role of Technology

TMOD is facing a significant challenge in its new role. NASA and other space agencies have embarked on a new era of space exploration. The number of missions is increasing, drastically.

Figure 2 shows a plot of the number of simultaneous deep space missions from 1980 through 2005. These data are based on projections of planned missions from various NASA roadmaps. The lower curve represents missions that can actually be named and have some planning associated with them. That curve grows from a value of about 10 today to over 25. Dan Goldin, the NASA Administrator, has a goal of a dozen deep space launches each year. If we achieve that goal, the result is the upper, gray line. In this case, there will be more than 50 missions at a time.

Either way, TMOD must be able to provide all of these additional services with a budget that is not likely to grow. The challenge is even greater considering these future missions will tend to be performed with smaller spacecraft.

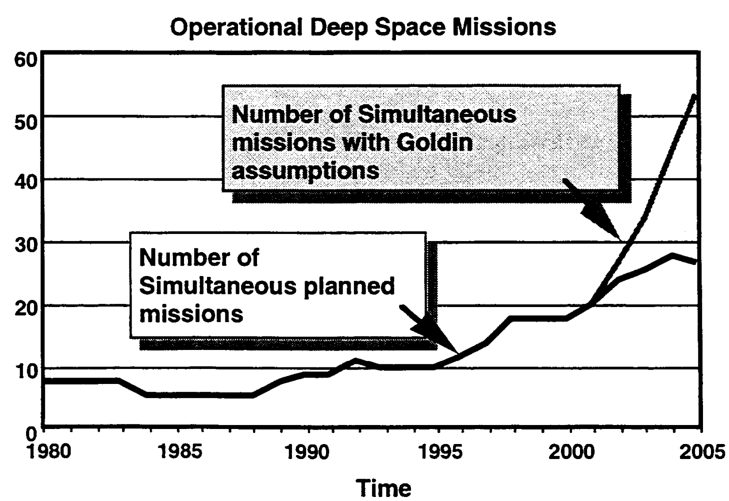

FIGURE 2. SIMULTANEOUS DEEP SPACE MISSIONS

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Improvement in the Water Vapor Emission Model from GPS/WVR Comparisons

Roger P. Linfield

RADIO SCIENCE RESEARCH

Introduction

An advanced troposphere calibration system, based on a Water Vapor Radiometer (WVR), is being developed for support of Cassini Radio Science experiments. In particular, the noise level (dimensionless strain sensitivity) for the Gravitational Wave Experiment (GWE) will be limited, to a large extent, by the calibration accuracy of tropospheric microwave delay changes on 100–10,000 s timescales.

One significant error component in any WVR-based calibration system involves the water vapor emission model. We measure sky brightness temperatures with a WVR. In order to convert these measurements into microwave path delays, we need to know the emission coefficient of water vapor. This coefficient is currently known to 5%–7% accuracy — we need a factor of two improvement for GWE.

GPS/WVR Comparison

Measurements of transmissions from the Global Positioning System (GPS) satellites can be used to determine the microwave delay from the earth's troposphere. Comparison between GPS and WVR measurements from the same site yields the ratio between these GPS delay measurements and the WVR brightness temperatures, and allows the water vapor emission coefficient to be determined.

Our initial test of this technique was done at Goldstone in the summer and fall of 1996. We operated two WVRs and two GPS receivers nearly continuously at DSS 13. The sampling interval for the GPS data was five minutes. The WVR data was interpolated to the epoch of the GPS data for comparison purposes. Figure 1 shows the GPS and WVR delay time series for the wettest and longest (42 days) segment of data. (The differences are too small to be seen when printed in black and white).

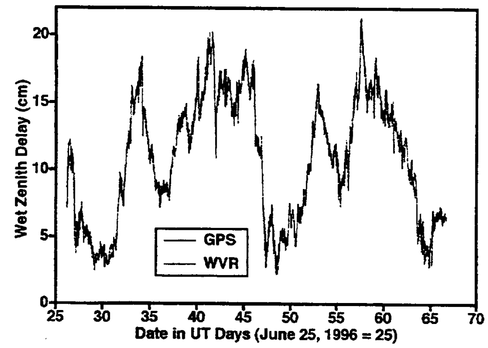

Figure 1. GPS and WVR Wet Zenith Delays at Goldstone for Data Segment 1

Table 1 gives statistics on the mean wet delay, and GPS/WVR agreement for each of our four data segments.

Future Work

The standard deviations from our Goldstone test are approximately equal to the rms sum of estimated GPS and WVR errors. For the relatively small total wet tropospheric delays at Goldstone, we cannot yet improve our knowledge of the water vapor emission coefficient. However, we expect GPS/WVR comparisons at a warm, humid site (e.g. Florida, the Texas coast, or Hawaii) to yield a more accurate comparison. For our 'humid site' experiment, we plan to add measurements from one more instrument. A microwave temperature profile, using passive observations in the 60 GHz band of molecular oxygen emission, measures the temperature vs. height in the lower troposphere. These temperature profiles reduce the errors in the interpretation of WVR brightness temperatures.

Table 1. Statistics on GPS-WVR Comparison

Segment Dates	Mean WVR Delay (cm)	Mean GPS/WVR Difference (mm)	Std Dev. of 5 min. values (mm)	Standard Dev. of 24 hr. avg. (mm)
6/25–8/6	10.5	2.0	5.3	2.9
8/14–8/26	9.2	3.1	5.2	2.2
8/27–9/10	8.8	4.0	6.4	3.3
9/17–10/6	6.6	4.3	4.5	2.1